

EVALUATION OF ESTIMATION OF ABUNDANCE OF SFAN JUVENILE COHO SALMON POPULATIONS

Report by:

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Estimates of juvenile coho salmon abundance are computed annually from stream surveys conducted by SFAN personnel. These surveys consist of a snorkel survey followed by multi-pass electrofishing in a subset of selected pools. Historically, the subset of pools has consisted of index reaches that are monitored annually as a legacy data set. This subset was subjectively-chosen and is not a true random sample as would be preferred for a true two-phase sample. The electrofishing counts are analyzed with Microfish Software to get estimates of the abundance of the juvenile population size present after the snorkel survey. Then the Hankin-Reeves (1988) estimator, a ratio estimator of the population estimate (the snorkel counts plus the Microfish estimate), is used to obtain an estimate of juvenile coho abundance across all sampled reaches.

The purpose of this report is to evaluate the existing literature and SFAN survey data to determine if the methods described above represent an unbiased approach to estimating juvenile coho abundance.

REVIEW OF LITERATURE FOR ESTIMATING FISH ABUNDANCE

Detection error is a form of nonsampling error, which arises from the imperfect execution of the sampling design (Lessler and Kalsbeek 1992). Detection error is a measurement error that is often biased low. Observers in ecological surveys often do not see all of the individuals of interest, causing observed counts to underestimate the true number of individuals present. An estimate of the detection probability or relative bias is needed to correct observed counts and obtain unbiased estimates.

The Hankin and Reeves (1988) estimator of abundance was developed to account for imperfect detection probabilities in snorkel surveys of fish populations in streams. The survey design for the Hankin and Reeves estimator employs a double sample. A systematic random sample of pools is surveyed by snorkeling in the first phase, and the second phase involves surveying a random subsample of pools with a more expensive but more accurate method of estimating abundance. The ratio of snorkel counts to the estimate from the more accurate method is used to adjust the counts in the first phase and obtain a bias-corrected estimate of fish abundance.

Multi-pass electrofishing is used by Hankin and Reeves (1988) to calibrate snorkel counts. However, multi-pass electrofishing is also known to underestimate the true population size. Rodgers, et al. (1992) used two-pass electrofishing methods and compared the results to snorkel counts and mark-recapture estimates from a study conducted in a stocked creek. Summer capture efficiencies were estimated as 40% for snorkel counts, 67% for removal estimates, and 85% for mark-recapture estimates. Winter capture efficiency for mark-recapture estimates was similar to summer estimates at 87% but the estimate was less precise. The majority of the variability in estimates of summer capture efficiency was explained by pool surface area (removal and mark-recapture) and rootwad volume as a percentage of pool volume (removal). The mark-recapture estimates were unbiased for small pools but biased for large pools.

Thompson (2003) outlines the limitations of the Hankin-Reeves approach, specifically the assumptions that the removal estimates are unbiased estimates of the true abundance and are highly correlated with the snorkel counts. Thompson (2003) found that the Hankin and Reeves estimate performs poorly unless the removal estimate represents at least 85% of the true population total and the correlation between removal estimates and snorkel counts is at least 0.9. Recommendations include incorporating environmental variables that influence detectability into the removal or mark-recapture estimate.

Peterson, et al. (2004) evaluated the use of multi-pass electrofishing in abundance estimates of salmonids. The authors found that three-pass electrofishing methods overestimated capture efficiency by 39% on average. Abundance was underestimated by removal methods by 116% for bull trout and 60% for cutthroat trout populations in Idaho and Montana. The first-pass capture efficiency for electrofishing was 28% and declined with subsequent passes, indicating that fish behavior changed in response to the survey methods. This behavior violates the assumption of equal capture probabilities required to calculate removal estimates with MicroFish software (Van Deventer and Platts 1983).

Rosenberger and Dunham (2005) examined removal and mark-recapture estimates for salmonids in small streams. Their research determined that the assumptions were met for mark-recapture estimation and unbiased estimates of abundance were obtained for this technique. However, the equal capture probability assumption was violated for multi-pass electrofishing methods and capture efficiencies ranged from 63-75% for two- to four-pass removal methods.

In summary, detection error is a serious concern for removal estimates from multi-pass electrofishing methods. Removal estimates from electrofishing were found to be negatively biased, and capture probabilities decline during multiple passes which violates the assumption of equal capture probability for abundance models. Mark-recapture estimates were found to be unbiased for small streams but negatively biased for larger streams. The bias of removal estimates and mark-recapture estimates varied by habitat characteristics such as stream size and complexity.

SFAN JUVENILE COHO DATA

Darren Fong provided snorkel counts and electrofishing removal estimates for surveys conducted in years 1998, 2005, 2006, and 2007 within Redwood, Pine Gulch, and Olema Creeks. Fong also provided data from a dewatered reach in Redwood Creek where juvenile coho were removed from the reach using snorkeling, seining, and electrofishing prior to removal during dewatering. These data will be used to assess the two requirements of Thompson (2003) for the use of Hankin-Reeves estimation methods.

Analysis of correlation

Correlation between the snorkel counts and electrofishing removal must be at least 0.9 for proper application of the ratio estimator used in Hankin and Reeves' estimation method

(Thompson 2003). For the data set containing snorkel counts and removal estimates from the 1998, 2005, 2006, and 2007 survey years, Pearson's correlation coefficients were calculated for several groupings of the data, including all surveys across creeks and years, creeks within years, and years within creeks (Table 1). Most of the correlation coefficients fall above 0.9 with the exception of the correlation between snorkel counts and removal estimates during the 1998 surveys and surveys for which snorkel counts fall below 20 fish. See Appendix A for scatterplots and simple linear regression lines.

Table 1: Pearson's product-moment correlation test results and 95%-confidence intervals

Data set	Correlation Est.	95 %-CI on Correlation
All creeks and years	0.9188	(0.8943, 0.9379)
Redwood Creek	0.9167	(0.8798, 0.9426)
Pine Gulch Creek	0.9047	(0.8231, 0.9497)
Olema Creek	0.9004	(0.8374, 0.9398)
All Creeks - 1998	0.7882	(0.6457, 0.8777)
All Creeks - 2005	0.9335	(0.8852, 0.9619)
All Creeks - 2006	0.9553	(0.9266, 0.9729)
All Creeks - 2007	0.9544	(0.9180, 0.9748)
Snorkel counts < 10	0.8196	(0.7398, 0.8766)
Snorkel counts < 20	0.7758	(0.6967, 0.8363)
Snorkel counts < 50	0.9152	(0.8864, 0.9370)

The correlation analysis of the SFAN juvenile Coho data indicate that Thompson's (2003) assumption is met for larger populations with higher snorkel counts. The low correlation between 1998 snorkel counts and removal estimates may be an effect of differences in observers, methodologies, or environmental conditions. The assumption of highly correlated counts and estimates ensures that the ratio estimator is appropriate but does not address potential bias in the estimate of abundance.

Capture probabilities

Thompson (2003) also requires that removal estimates represent at least 85% of the true abundance to obtain unbiased Hankin-Reeves estimates. A census of juvenile coho salmon was obtained in a reach of Redwood Creek using seining, snorkeling, and multi-pass electrofishing methods two weeks prior to dewatering and complete removal of the population. If one is willing to assume that the population two weeks prior is the same population that was removed, then these data may be very helpful in testing Thompson's (2003) assumption of that electrofishing removal estimates account for at least 85% of the true population.

Twelve units of Redwood Creek were surveyed in this pilot study (Table 2). A "unit" represents either a pool or a collection of contiguous pools. Some sets of pools were

treated as one unit because the juveniles were combined during removal and the original pool of origin was not documented.

Three of the four pools that were snorkeled were subsequently seined before electrofishing began. This methodology differs from the standard SFAN methodology in that seining is not usually done between the snorkel and electrofishing surveys. For this reason, assessing the performance of the Hankin-Reeves (1988) estimator for the SFAN surveys is not possible. However, true capture probabilities of the different survey methods may be calculated because the true population size is known after dewatering.

Two or three electrofishing passes were used in each unit. Estimates from Microfish Software, which are calculated from the maximum likelihood estimate of the number of fish not detected, increased the total observed electrofishing counts by only one fish. This small model adjustment produces a small standard error in this analysis. Removals from dewatering totaled only 9 juveniles, indicating that previous efforts removed most of the juvenile coho present. The most effective removal method was seining, which accounted for 45% of the total removals. However, seining is not a standard SFAN juvenile coho survey method.

True capture probabilities were calculated over all units by dividing the number removed for each method by the number of juveniles present at the time the removal method was used (Table 2). The true capture probability of snorkel surveys was 0.36, which is quite comparable to the snorkeling capture probability of 0.4 observed by Rodgers, et al. (1992). The true capture probability of seining was 0.71, indicating that this method is almost twice as effective as snorkeling. Microfish Software generates estimates of abundance only when fish are observed in more than one electrofishing pass. The true capture probability of electrofishing removal estimates was calculated using the sum of the Microfish estimates, when available, and the observed electrofishing removal counts when Microfish estimates could not be calculated. The true capture probability of electrofishing removal estimates was calculated as 0.85, which is what Thompson requires as a minimum for unbiased use of the Hankin-Reeves estimator.

Using large-sample theory, the 90%-confidence interval for the estimate of total abundance is (284.22, 291.78); this interval does not cover the true population size of 296. The underestimation of the abundance estimate may be caused by a combination of nonlinear association of snorkel counts and electrofishing removal estimates for small juvenile populations (less than 30 observed during snorkel counts) or an electrofishing removal estimate capture probability that achieves the minimum required to account for bias. Variances for estimates across all units are calculated by summing the variances across pools. This naïve approach assumes that units are uncorrelated. Dewatering occurred 2 weeks after the snorkel, seine, and electrofishing surveys were conducted, so the population was not closed for the extent of the experiment. All of these factors may contribute to the accuracy and precision of the abundance estimate.

Table 2: Removal results from the Redwood Creek juvenile coho survey

Unit	Snorkel	Seine	Efish 1	Efish 2	Efish 3	Efish abundance estimate (SE's from Microfish)	Est. Efish removal estimate capture probability	Dewater removal counts	True Abundance	Est. Abundance	True Efish removal estimate capture probability	True snorkel capture probability	True seining capture probability
Euc. Grove		0	9	1		10 (0.346)	0.909 0.104)	3	13	10	0.77		0.00
Bowling Alley			0	0		0	0	0	0	0			
158		0	10	4		15 (2.262)	0.700 (0.193)	0	14	15	1.00		0.00
159	1		1	0	0	1		0	2	2		0.50	0.00
160			0	0		0		0	0	0			
161		10	1	0		1		0	11	11			0.91
162, 163, 164		42	6	0		6		1	49	48			0.86
165	31	23	10	2	0	12 (0.201)	0.857 (0.101)	5	71	66	0.71	0.44	0.58
166, 167			0	0		0		0	0	0			
168			0	0		0		0	0	0			
169, 170	8	15	0	0	0	0		0	23	23		0.35	1.00
171	67	44	2	0	0	2			113	113		0.59	0.96
TOTAL	107	134	39	7	0	47 (2.297)		9	296	288 (2.297)	0.85	0.36	0.71

Differences in this pilot study and the standard SFAN juvenile coho surveys may make inference from this analysis spurious. Seining is not used in the standard SFAN juvenile coho surveys. Seining capture probabilities from this pilot study are quite variable and range from 0% to 100% of the fish present. Results from this pilot study indicate that seining may be a more effective method for first pass removals when juvenile populations exceed 10 to 15 fish, but this method may be too labor-intensive to use in the standard survey methodology. Snorkeling was used only in four units and exhibited unit-level capture probabilities ranging from 0.35 to 0.59. The population of juvenile coho remaining after snorkeling and seining was only 55 fish; this is a very small population on which to based efficiency estimation. These results are encouraging but ultimately inconclusive.

CONCLUSIONS

SFAN pilot data indicates that multi-pass electrofishing provides estimates that are highly correlated (>0.9) when snorkel counts exceed 30 fish and exhibits capture probabilities of about 85% after both snorkeling and seining surveys are conducted. The results of Thompson (2003) would suggest that this method is adequate for calibration of large (>30) snorkel counts within SFAN streams. If electrofishing would be less effective in the absence of prior seining, then electrofishing removal capture probabilities may be lower in practice. Further research should be employed to test the bias of juvenile coho abundance estimates obtained from the survey protocol used by SFAN.

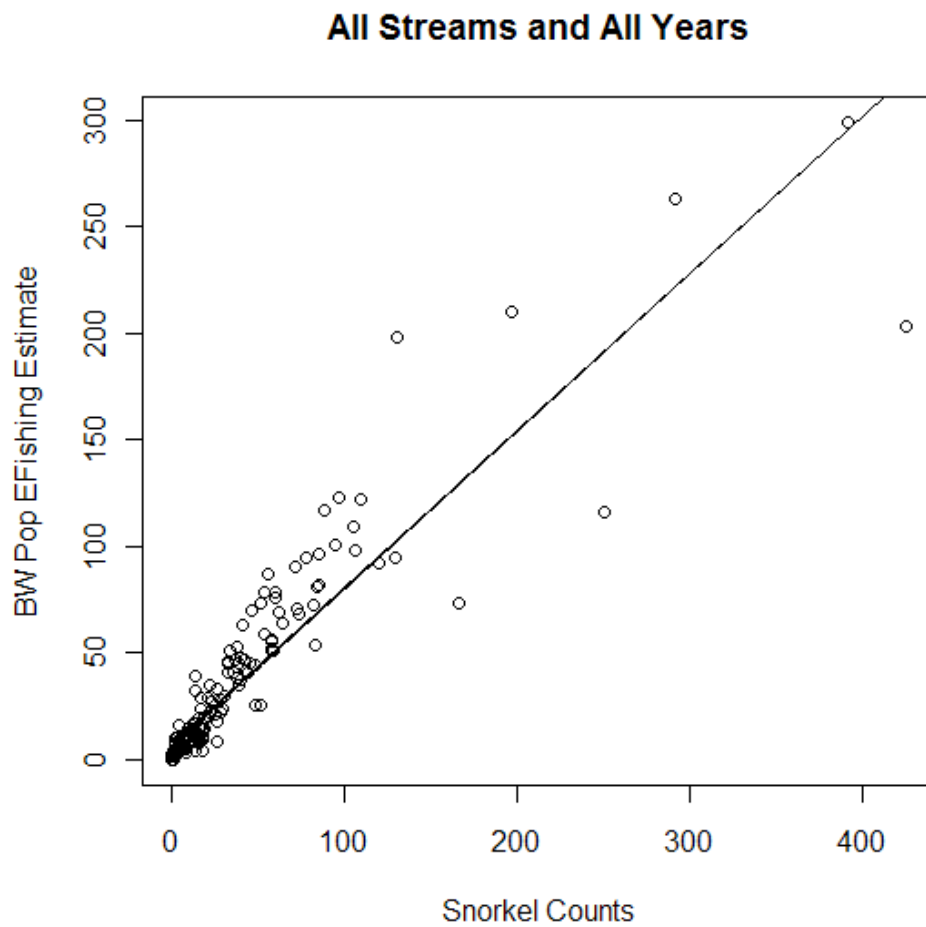
A pilot study that does not incorporate seining would be helpful in directly assessing the performance of the Hankin-Reeves estimator. The bias of this estimator should be evaluated for populations found in pools in which less than 30 juvenile salmon were observed during snorkel surveys. Incorporating mark-recapture estimation to assess the bias of multi-pass removal estimates would provide additional information on methods for estimating juvenile coho abundance in SFAN streams. A pilot study should also employ randomization when appropriate. The survey should be designed so that bias may be assessed within levels of habitat characteristics that influence the bias of multi-pass electrofishing removal estimates as in Rodgers, et al. (1992).

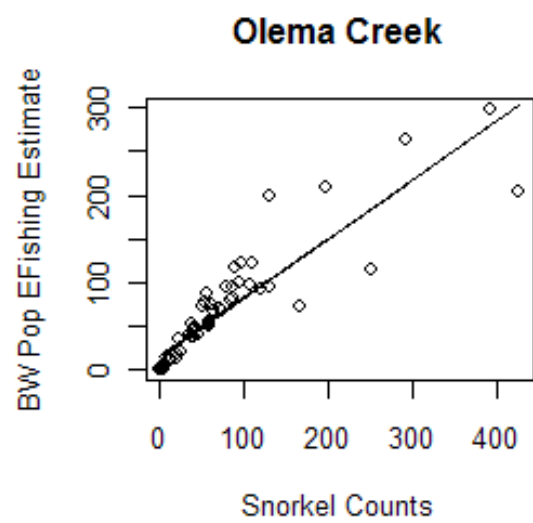
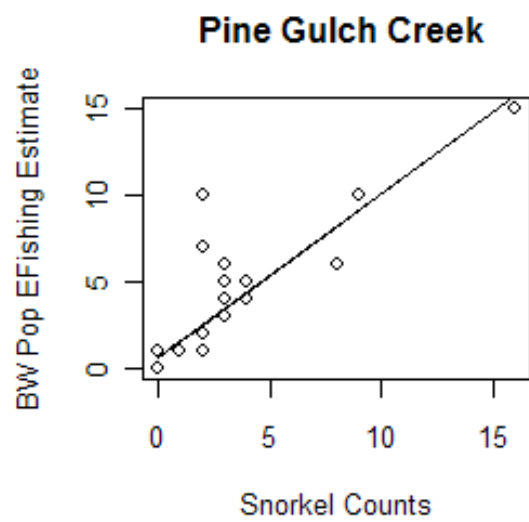
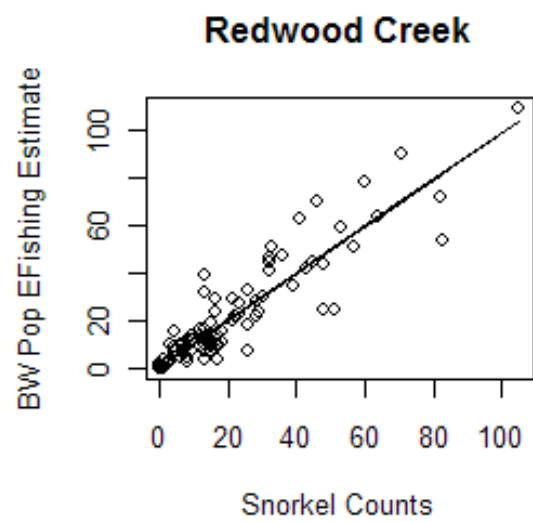
For any calibration method, the calibration survey method used during the second phase should be conducted within a true subsample of pools rather than a selected subset based on convenience.

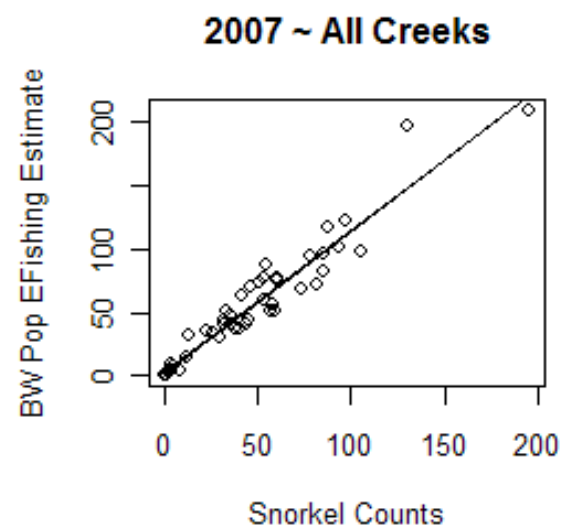
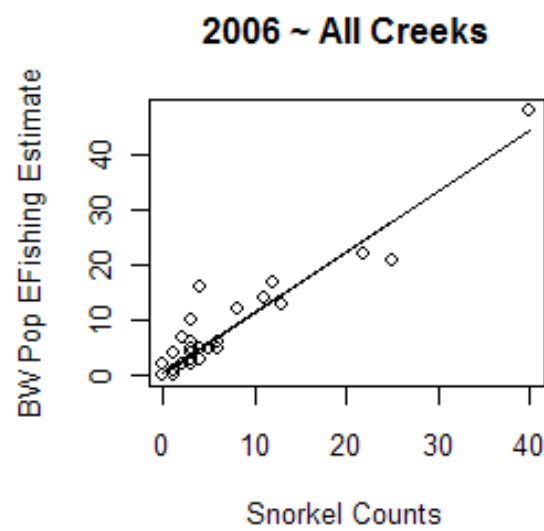
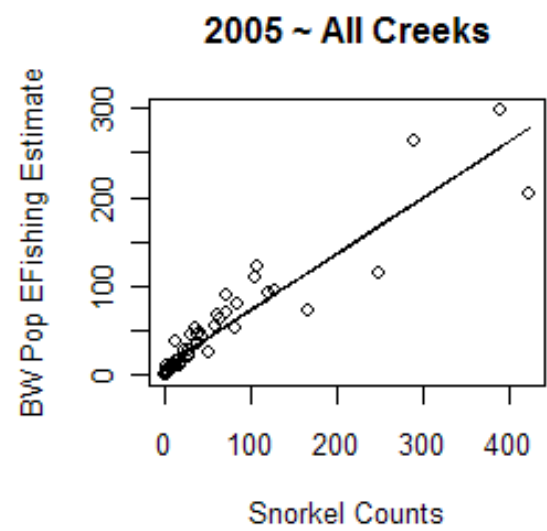
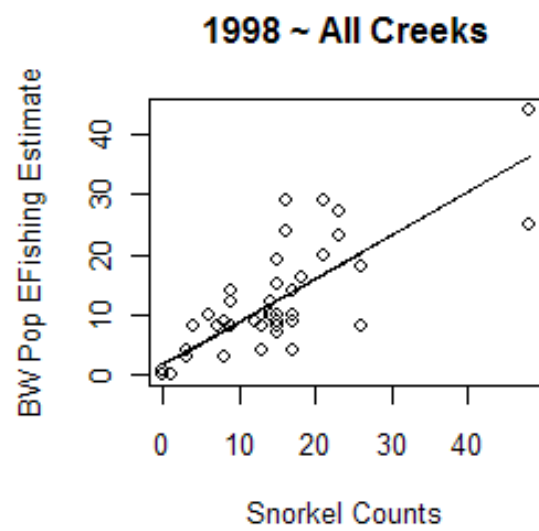
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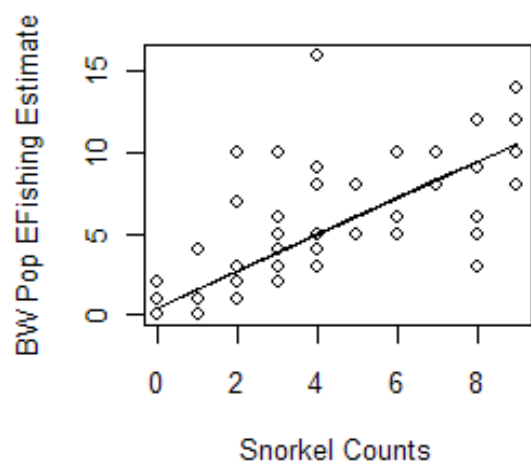
Appendix A: Scatterplots of removal estimates versus snorkel counts with simple linear regression fit for several data subsets



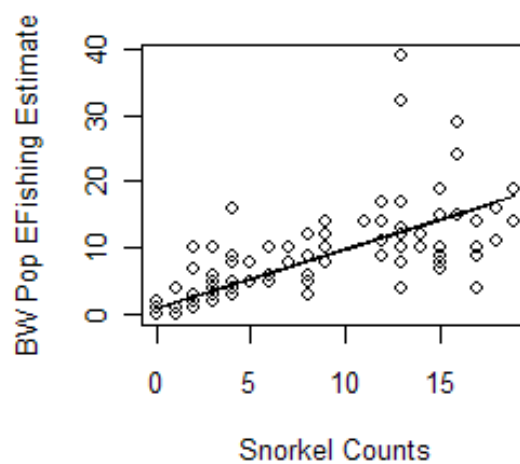




Snorkel Counts < 10 Coho



Snorkel Counts < 20 Coho



Snorkel Counts < 50 Coho

